LOW EMISSIONS WITH MICROEMULSION-FUELS

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Abstract

The advantageous effects of water on the combustion of diesel-fuel have been repeatedly studied over the past thirty years. However, the thermodynamic instability of emulsions has remained an unsolved problem. In a new approach we developed water-fuel-microemulsions, which are thermodynamically stable. We paid special attention to high efficiency and temperature invariance. Furthermore, using biogenic additives, as well as microemulsificating of biogenic fuels such as Biodiesel and BtL (Biomass to Liquid) contributes to environmental sustainability. In a number of combustion investigations on the engine test benches we were able to confirm a reduction of 70% to 80% of soot exhaust concomitant with a substantial NO_x reduction during engine operation. Thus, the diesel dilemma or soot-NO_x-trade-off is overcome.

Introduction

Pollutant formation by combustion of fossil and biogenous fuels is still an unsolved problem. Internal combustion engines are significant contributors to air pollution, such as NO_x and particulate matter. The investigations of different groups have shown that the increase of the oxygen content in blend fuels with additives such as ester, ether, acetals, alcohols etc. cause the reduction of soot emissions [1-3]. The advantages of changing fuel compositions are not only the reduction of pollutant emissions but also the reduction of the CO_2 emission by use of biogenous additives [4]. The addition of water leads to a reduction of nitrogen oxide and soot emissions at the same time. In published reports there are several ways which have already been tested, *e.g.* direct water injection into the combustion chamber [5] or the use of water-containing fuel. Such fuels are already available as water-fuel emulsions [6]. Unfortunately, emulsions do not exhibit long-term stability as they separate into an aqueous and an oily phase after a certain time [7]. The combustion of the emulsion droplets is frequently accompanied by the micro-explosion phenomenon, due to the volatility difference between the water and the fuel [8]. Due to the lower combustion temperature the formation of thermal (Zeldovic) NO is reduced [9].

Results and Discussion

The best way to produce a homogeneous mixture of two immiscible liquids as water and fuel is a microemulsion. The use of microemulsions offers several advantages for the combustion process. Beside the thermodynamic stability of the microemulsified aqueous fuel, water, surfactants, and freezing point-decreasing components that are homogeneously distributed on a nano-scale can be optimally used for the reduction of soot and NO_x emissions. Microemulsions form spontaneously and exhibit nano-disperse structures. In contrast to emulsions there is no additional energy input necessary for the production of a microemulsion. The formation is thermodynamically favoured due to the ultra-low interfacial tension between the oil and water domains. The microemulsified fuels are in principle thermodynamically stable for an unlimited period of time: only the chemical stability of the single components could be a limiting factor. A further advantage of microemulsions in contrast to emulsions is the fact that the water content can be adjusted over a broad range. Therefore the combustion process can be customized to specific needs. An important criterion for a microemulsion to be used as fuel is that the one-phase region extends over a wide temperature range (**Figure 1**). Mixtures of ionic and non-ionic surfactants, which exhibit almost temperature-invariant phase behaviour by optimal composition, are suitable to meet these standards.

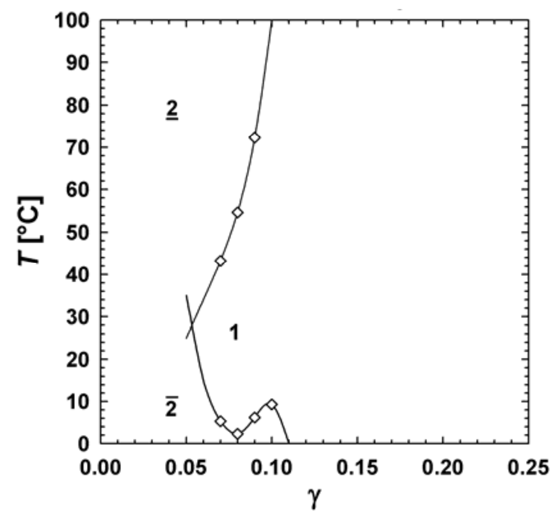

Figure 1. Enlarged one-phase area of a phase diagram obtained for the system H_2O/antifreeze – diesel – biogen surfactant/nonionic surfactant with 15 Wt.% Water (γ: surfactant mass fraction in the microemulsion).

Extensive investigations at the Institute for Mechanical Engineering and Vehicle Technology at the University of Applied Science in Trier as well as practical tests showed that soot emissions were lowered by more than 70/80% upon the application of water-diesel microemulsions (see **Figure 2**, upper panel). Interestingly the NO_x-particulate matter trade-off is avoided, *i.e.* nitrogen oxide emissions are also lowered significantly (**Figure 2**, lower panel). The surfactants used for the formation of the microemulsion are oxidised species, which, as already mentioned above, decrease the soot formation further.

The measured data shows that by the application of microemulsions as alternative fuel the combustion becomes cleaner. Microemulsions can be used successfully in both stationary and dynamically operated engines. In the stationary operation it appears reasonable to use the microemulsion with a defined water content. In this case water content can be individually adapted for the respective engine load. In vehicles the engines are operated under a permanent engine load change, therefore the water/fuel ratio must be adapted to the respective operating point. This punctual adjustment ensures minimum of pollutant emissions and favourable fuel consumption. The use of the microemulsions in all conceivable kinds of combustion engines makes the selection of optimal burning technologies with minimum pollutant emissions and improved degree of efficiency a route which has not yet received the attention it deserves.

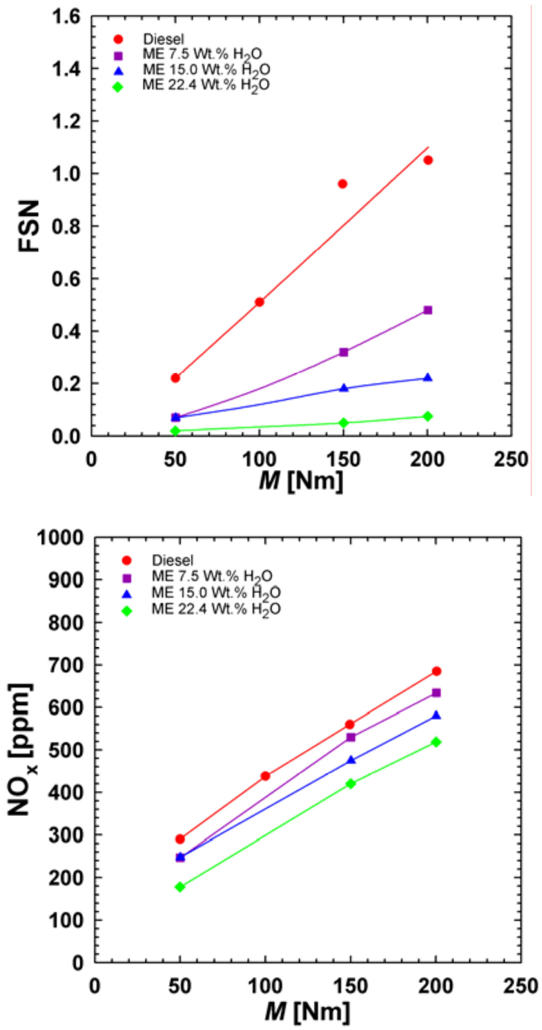

Figure 2. Soot in units of the filter smoke number (*FSN*) (upper panel) and NO_x (lower panel) emissions of microemulsified fuels with varying water content for combustion measured as function of torque *M*. The measurements are carried out on a Deutz engine, 82 kW, 4-cylinder, without EGR by constant 1800 r.p.m. as a function of the engine load condition (Department Mechanical Engineering, University of Applied Science, Trier).

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